Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 4, No. 12, December, 2018

Influence of Reduced Water Cement Ratio on Behaviour of Concrete Having Plastic Aggregate

Saad Tayyab [a*], Asad Ullah [a], Kamal Shah [a], Faial Mehmood [a], Akhtar Gul [a]

[a] *Department of Civil Engineering, UET Peshawar, Campus-III Bannu 28100, Pakistan.*

Received 08 September 2018; Accepted 05 December 2018

Abstract

The production and use of plastic bottles is increasing tremendously with passing time. These plastic bottles become a problem when they are disposed as they are non-biodegradable. This means that the waste plastic, when dumped, does not decompose naturally and stays in the environment affecting the ecological system. The use of alternative aggregates like Plastic Coarse Aggregate (PCA) is a natural step in solving part of reduction of natural aggregates as well as to solve the issue discussed above. The researchers are trying from half a century to investigate the alternative materials to be replaced in concrete mixture in place of either aggregate or cement. In this research, the concrete made from plastic waste as coarse aggregates were investigated for compressive strength and Stress-strain relationship. Plastic coarse aggregate have been replaced in place of natural coarse aggregate by different percentages with w/c 0.5, 0.4 and 0.3. The percentage replacement of plastic aggregate in place of mineral coarse aggregate was 25%, 30%, 35% and 40 %. Using Super-plasticizer Chemrite 520-BAS. OPC-53 grade cement was used. Total of forty five Cylinders were prepared based on different combination of Percentage of Plastic aggregate replaced and W/C as discussed above and checked for compressive strength and stress-strain relationship. The compressive strength increases by about 19.25% due to the decrease in W/C from 0.5 to 0.3 for plastic percentage addition of 40%.

Keywords: Plastic Aggregate; Concrete; Compressive Strength; W/C; Super Plasticizer.

1. Introduction

There is no doubt that plastic is a wonderful invention, if you look around you will find everything or has some amount of plastic or made entirely of plastic. Plastic is used everywhere, from simple things like kitchen utensils toys, to the most complex machines and computers. Therefore, it is clear that plastics are the important part of our life. The best advantage of plastic is that it can be molded into any desired shape easily. On the other hand, metal requires a lot of efforts. Plastic offers such a good sturdiness and durability compare to other materials [1].

Compare to other materials like metals and wood, Plastic is a cheap material. The reason behind is that the melting point of plastic is less than the metal products (The melting point of cast iron is 1204 ^{o}C), can be molded into any desired shape easily [2]. Plastic is also chemically resistant, means it does not react with chemical easily making it suitable for preserving medical items and food [3]. Plastics used in construction and building and are durable materials. Use of plastics can be seen in plastic pipes and window frames [4].

In the last 20 years, a lot of efforts have been made to effectively used waste products on the effective use of waste material such as plastic. By recycling method, these wastes are converted into plastic aggregates after collecting from disposal area. Coarse aggregate is then replaced by these recycled plastic in concrete up to a specific percentage.

* Corresponding author: saadtayyab2@gmail.com

http://dx.doi.org/10.28991/cej-03091213

Plastic aggregate is having a very low density as compared to minerals aggregate that is why if we replace mineral aggregate with plastic aggregate up to some extent then the resulting product will be lightweight concrete. Consuming waste plastic in concrete up to some percentage make the structures light weight as well as eco-friendly, and can be fruitful in the construction and design of skyscrapers. The main advantage of plastic aggregate over other light weight aggregate is that other light weight aggregates and their preparation processes are too expensive than the plastic aggregate and that's the reason that the researchers are more attracted toward the plastic aggregate than other light weight aggregate. And nowadays technology is so progressive and to achieve strength, durability and resistance to impact, the building materials will be gradually combined with recycled plastic products [5].

Marzouk et al. substitute the fine particles of concrete mix with the PET bottles waste up to some extent and determine the effects produced from this replacement on the hardened concrete in the form of compressive strength and density. They concluded from their research that both the density and strength is decreases by replacing coarse aggregate with PET aggregate more than 50% by volume of fine aggregate [6].

Frigione prepared concrete mix having PET with a W/C of 0.45 and determine the strength in compression and stress-strain curve by comparing with the reference concert mix. The strain value that correspond to maximum value of stress for concrete having PET aggregate was 0.0018 with elastic modulus of 48.1 GPa, while for the reference material the said value were 0.0020 and 41.8 GPa respectively [7].

To evaluate the concrete mechanical properties, Marthong used PET fibers; his research was to investigate the concrete mechanical properties by using fibers with different dimensions and geometries. Replacing 20% of coarse aggregate by plastic aggregate can be incorporated in concrete mixture deprived of any long-term negative effects and with allowable strength development properties. Results from his research showed that by increasing the plastic aggregate more than 20% the strength noticeably decreased and the workability of concrete was effected to a very small extent [8]. Another research work were carried out in 2007 to evaluate the properties of concrete having plastic aggregate. Fine aggregate was replaced with plastic waste for different percentages of 0%, 10%, 15% and 20%. Total of 70 cubes were prepared for compressive strength. The conclusion of these tests stated that by increasing waste plastic in concrete decreases the compressive strength as compare to reference concrete at all curing ages [9]

Pramod et al. partially replaced natural coarse aggregate with industrial plastic wastes from polypropylene (PP) and polyethylene terephthalate (PET). Concrete mixture was prepared with 10%, 20%, 30%, 40% and 50% replacement of plastic aggregate. By conducting tests on the material like normal aggregate, cement and sand and concluded that all the results were in the permitted limit as per codes. By replacing 20% of natural coarse aggregate in the concrete mix with plastic aggregate showed that the strength and other properties were in the permissible limit. According to IS codes the concrete mix having fractional replacement of natural coarse aggregate demonstrate that only 10% it could be satisfy. After 20% replacement of natural coarse aggregates with plastic aggregate in a concrete mix, density of concrete is reduced [10]. Araghi et al. in 2015 stated that the concrete mix having partial PET particles with natural coarse aggregate, shows excellent resistance to the attack of sulfuric acid in sewer pipes and industrial structures [11]. Raju Sharma and Prem Pal Bansal in 2016 determined that the concrete compressive strength decreases by replacing coarse aggregate with plastic aggregate. However, the performance of the concrete having plastic aggregate can improved with the help of suitable mineral admixtures and chemically treated plastic waste like alkaline bleach treatment [12].

Colangelo et al. in 2016 demonstrated that the strength in compression and density of lightweight concrete mixture decreases by increasing plastic aggregates. The decrease in the density of lightweight concrete shows that plastic aggregates are much lighter as compare to natural coarse aggregate [13]. In 2016, another research study reveals that due to the partially replaced recycled plastic aggregate with natural coarse aggregate, the concrete compressive strength was reduced between 40 and 53% as compared to the traditional coarse aggregate concrete [14].

Modern concretes usually have additives, either in the chemical form or mineral form. For the improving the workability of concrete mixture plasticizers and superplasticizers are added. Unless the mixture is "starved" of water, by increasing the water amount in the batch, the strength of resulting concrete mix decreases because the strength is inversely proportional to W/C. Less water should be added (except "starving" the mixture) to produce stronger concrete, which makes the batch harsh and less workable, demanding the use of superplasticizers, dispersants or water reducers.

It is advisable to add 1-2% plasticizer by weight of cement is frequently enough. Unwanted segregation of concrete mix will occur by the addition of excessive amount of plasticizer, which is not desirable. Sometimes it might results in retarding effects by the addition of excessive amount of plasticizer but the amount of plasticizer to be used depends on the specific chemical [15].

Therefore, the above reasons endorses the requirement of a study to promote the use of plastic coarse aggregate in high percentages. For which, this research has been planned to explore the compressive strength and stress strain relationship of concrete having higher percentages of plastic aggregate.

2. Materials and Methods

Concrete properties are greatly affected by gradation, surface texture and shape of the aggregates. More shear strength is provided by angular and rough-textured aggregates as compared to rounded shaped aggregates having smooth-texture. According to the standards and specifications of ASTM and BS for material characterization, mandatory tests were performed on utilized aggregates and all the results were within the specified limit. Figure 1 and 2 present gradation curve of coarse and fine aggregate respectively.

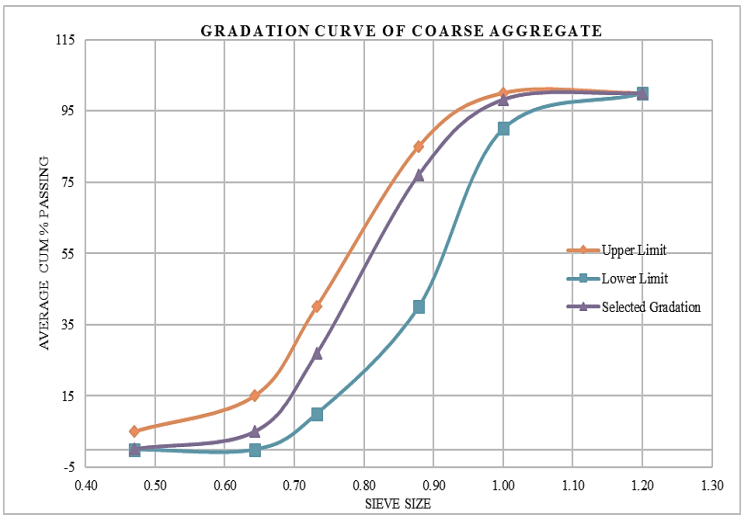

Figure 1. Gradation curve of coarse aggregate

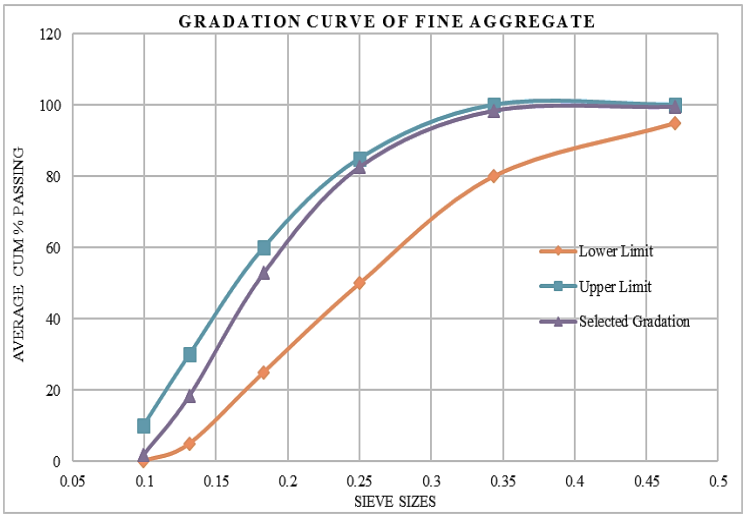

Figure 2. Gradation curve of fine aggregate

Chemrite 520 BA-S as superplasticizer for W/C reduction. From Slum tests, we have defined the percentages of super plasticizer required for each type of concrete mix. Performing three trials for each type of concrete mix the required workability was obtained by adding superplasticizer of 0.75%, 1% and 2.5% for W/C of 0.5, 0.4 and 0.3 by weight of cement respectively as the recommended range for super plasticizer used (Chemrite 520 BA-S) is 0.6-3% by weight of cement. Mix Design for concrete specimen is given below in Table 1.

Table 1. Mix Design of Concrete

Ratios	Cement : Fine Aggregate : Coarse Aggregate : Plastic Aggregate		
	W/C = 0.5	**W/C = 0.4**	**W/C = 0.3**
0 %	1:2.08:3.20:0.00	1:1.50:2.56:0.00	1:0.92:1.92:0.00
25 %	1:2.08:2.40:0.42	1:1.50:1.92:0.34	1:0.92:1.44:0.25
30 %	1:2.08:2.24:0.51	1:1.50:1.79:0.41	1:0.92:1.34:0.31
35 %	1:2.08:2.08:0.59	1:1.50:1.66:0.47	1:0.92:1.25:0.36
40 %	1:2.08:1.92:0.68	1:1.50:1.53:0.54	1:0.92:1.15:0.41

For each of the concrete mix based on w/c of 0.3, 0.4, and 0.5 and plastic percentage of 0%, 25%, 30%, 35%, and 40% three concrete cylinders were caste of size 300 mm depth and 150 mm diameter. Thus a total of 45 concrete cylinders were casted and tested after 28 days under compression as per ASTM standard C470/C470M-15 are given in Figure 3 and 4 and Table 2 present the compression test results with comparison in Figure 5. The crack patterns of concrete cylinders having plastic aggregates and normal coarse aggregates are shown in Figure 6 and 7 respectively. And stress strain curves are shown in Figure 8 to 10.

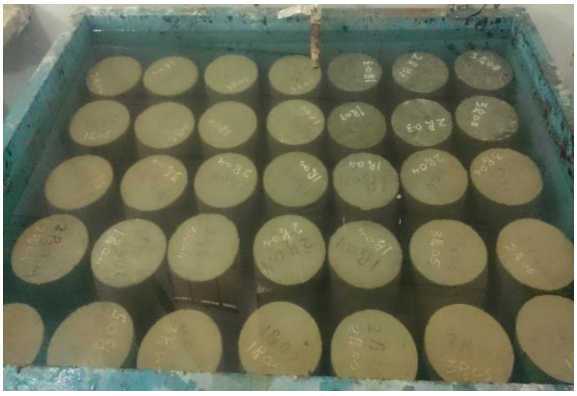

Figure 3. Curing of concrete cylinders for 28 days

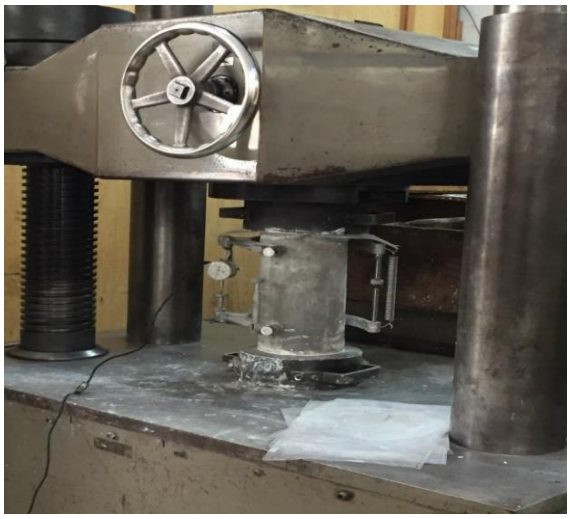

Figure 4. Testing of concrete cylinders for compression Test

Table 2. Compression Tests Result

	W/C = 0.5		W/C = 0.4		W/C = 0.3	
Percentage of Plastic	**Average Strength (Psi)**	**Percent Reduction in Strength**	**Average Strength (Psi)**	**Percent Reduction in Strength**	**Average Strength (Psi)**	**Percent Reduction in Strength**
0	3935	0	5047	0	6713	0
25	2919	26	3431	32	3675	45
30	2797	29	3137	38	3556	47
35	2638	33	2997	41	3038	55
40	2467	37	2877	43	2942	56

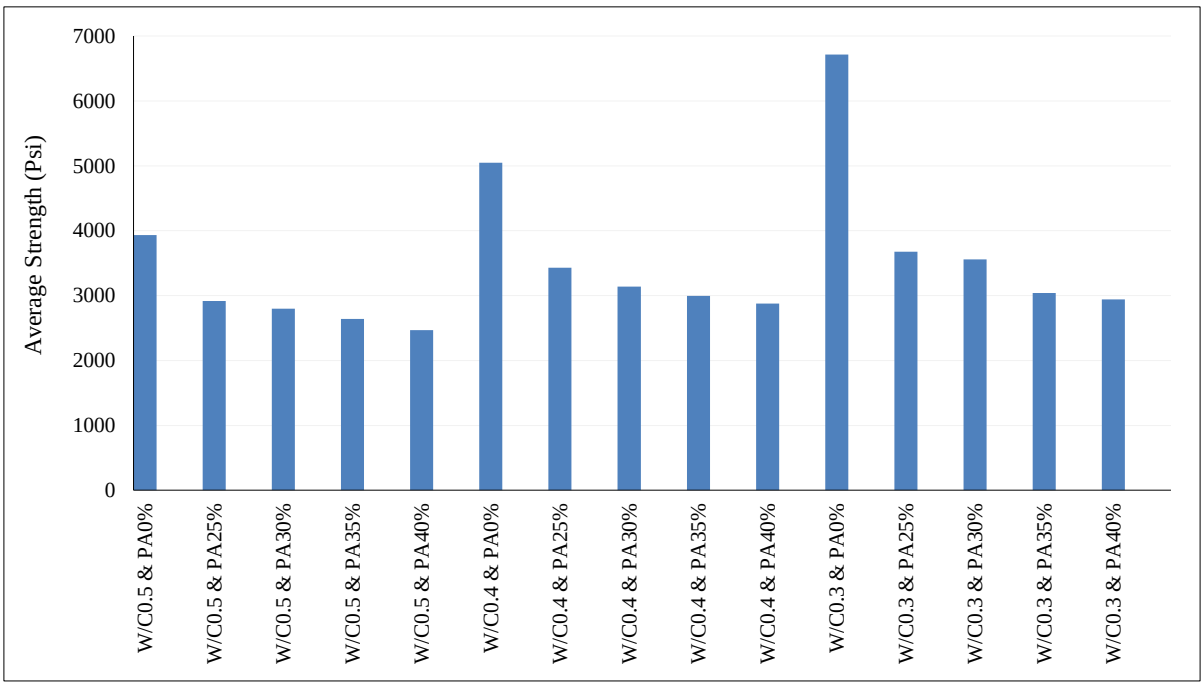

Figure 5. Compression Test result for different parentages with variable water cement ratios

Figure 6. Cracks pattern of plastic aggregate

Figure 7. Cracks pattern of normal aggregate

It is clear from the above two figures that the samples having plastic coarse aggregates show less and minor cracks as compared to natural coarse aggregates because these plastic aggregates provide better resistance to the propagation of micro cracks within the matrix.

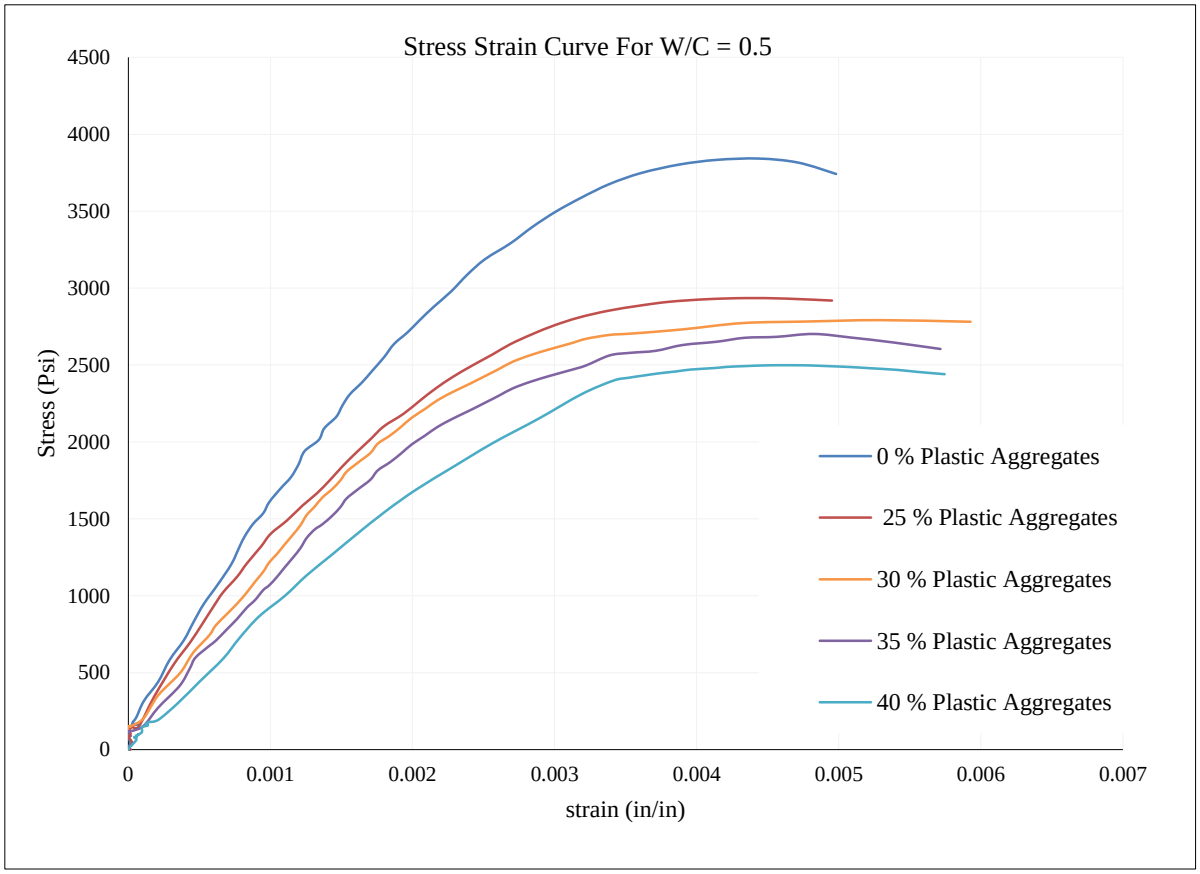

Figure 8. Stress Strain Curves for W/C 0.5 and Variable Plastic Percentages

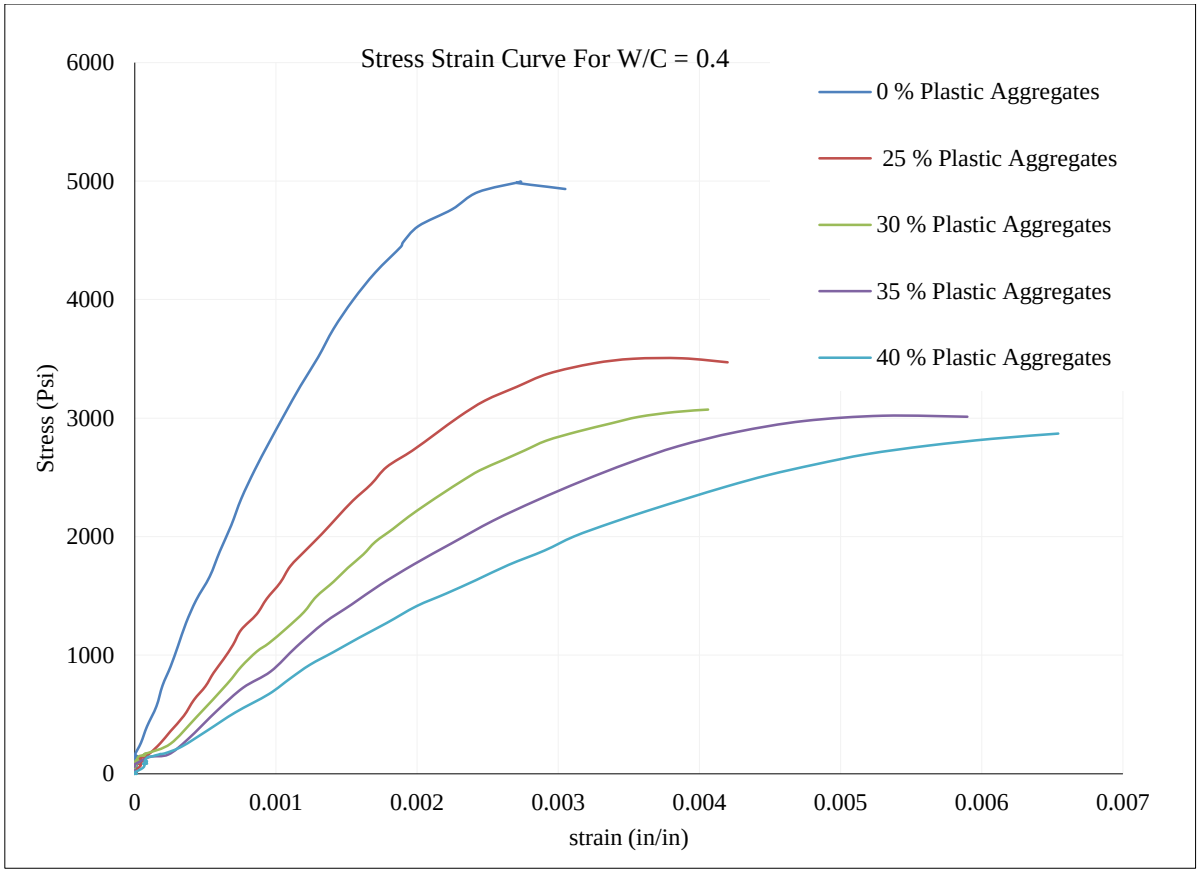

Figure 9. Stress Strain Curves for W/C 0.4 and Variable Plastic Percentages

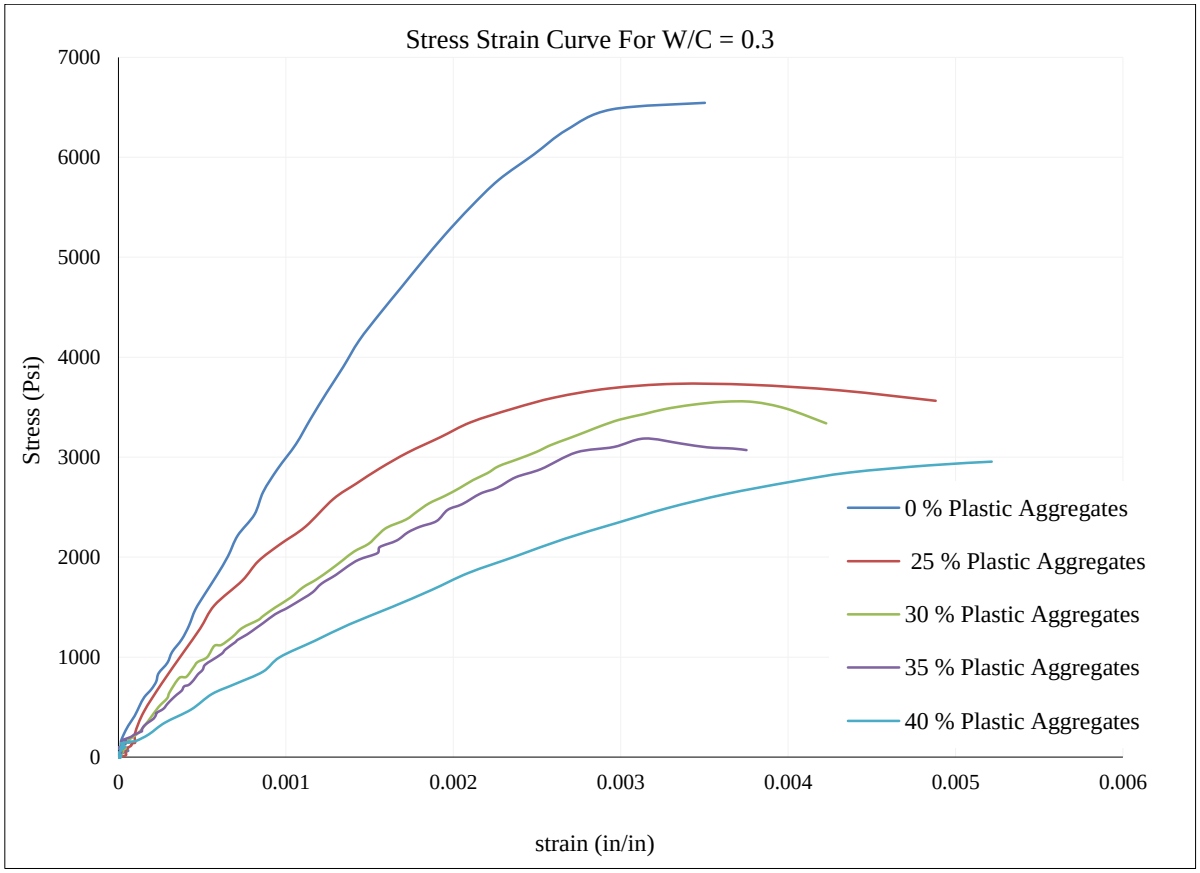

Figure 10. Stress Strain Curves for W/C 0.3 and Variable Plastic Percentages

3. Conclusions

Conclusions of this research work are given below.

- Concrete mix preparation with plastic waste in the form of plastic aggregates in place of local material can be conducted in the same fashion as that of traditional concrete.
- Reduced slump values of plastic aggregate in concrete mixtures indicates that it can be used in circumstances that require low workability.
- Weight reduction of 25-30% is possible through replacement of 40% plastic aggregate.
- Up to 40% replacement of plastic aggregate is possible through reduction of W/C of 0.3 with the addition of higher possible percentage of Superplasticizer.
- The compressive strength decreases with increasing plastic aggregate from 0% to 40% for all the W/C of 0.5, 0.4 and 0.3. The main reason of the decreased compression strength is the weak bond between the cement paste and the plastic aggregate and as a result, it disturb the internal arrangement of the concrete. This behaviour is important when some ductility of the material is necessary.
- Further, the compressive strength increases by about 19.25% due to the decrease in W/C from 0.5 to 0.3 for plastic percentage addition of 40%, this reduction of W/C is carried out by increasing percentage of superplasticizer from 0.75% by weight of cement for W/C of 0.5 to 2.5% by weight of cement for W/C of 0.3.

4. Conflicts of Interest

The author declares no conflicts of interest.

5. References

[1] Suryakanta. 10+ General Properties of Plastic as a Construction Material. civilblog. [Online] July 9, 2015. http://civilblog.org/2015/07/09/10-general-properties-of-plastic-as-a-construction-material.

[2] Nazaretian, Ryan Nicholas. Ethernet over plastic optical fiber for use in the control system network for automotive applications. Mississippi State University, 2015.

[3] Plastic Recycling and Sustainability British Plastic Federation. [Online]. www.bpf.co.uk/Sustainability/Plastics_and_Sustainability aspx.

[4] Statistik-Portal, Statista-Das. "statista–The statistics portal." (2014).

[5] Rossignolo, Joao A., and Marcos VC Agnesini. "Mechanical properties of polymer-modified lightweight aggregate concrete." Cement and Concrete Research 32, no. 3 (2002): 329-334. doi:10.1016/S0008-8846(01)00678-0.

[6] Marzouk, O. Yazoghli, R. M. Dheilly, and M. Queneudec. "Valorization of post-consumer waste plastic in cementitious concrete composites." Waste management 27, no. 2 (2007): 310-318. doi:10.1016/j.wasman.2006.03.012.

[7] Frigione, Mariaenrica. "Recycling of PET bottles as fine aggregate in concrete." Waste management 30, no. 6 (2010): 1101-1106. doi:10.1016/j.wasman.2010.01.030.

[8] Marthong, Comingstarful. "Effects of PET fiber arrangement and dimensions on mechanical properties of concrete." The IES Journal Part A: Civil & Structural Engineering 8, no. 2 (2015): 111-120. doi:10.1080/19373260.2015.1014304.

[9] Foley, Christopher M., and Evan R. Buckhouse. "Structural Engineering Report MUST-98-1 Strengthening Existing Reinforced Concrete Beams for Flexure Using Bolted External Structural Steel Channels." (1998).

[10] Patil, Pramod S., J. R. Mali, Ganesh V. Tapkire, and H. R. Kumavat. "Innovative techniques of waste plastic used in concrete mixture." International Journal of Research in Engineering and Technology 3, no. 9 (2014): 1-4. doi:10.15623/ijret.2014.0321008.

[11] Araghi, H. Janfeshan, I. M. Nikbin, S. Rahimi Reskati, E. Rahmani, and H. Allahyari. "An experimental investigation on the erosion resistance of concrete containing various PET particles percentages against sulfuric acid attack." Construction and Building Materials 77 (2015): 461-471. doi:10.1016/j.conbuildmat.2014.12.037.

[12] Sharma, Raju, and Prem Pal Bansal. "Use of different forms of waste plastic in concrete–a review." Journal of Cleaner Production 112 (2016): 473-482. doi:10.1016/j.jclepro.2015.08.042.

[13] Colangelo, Francesco, Raffaele Cioffi, Barbara Liguori, and Fabio Iucolano. "Recycled polyolefins waste as aggregates for lightweight concrete." Composites Part B: Engineering 106 (2016): 234-241. doi:10.1016/j.compositesb.2016.09.041.

[14] Alqahtani, Fahad K., M. Iqbal Khan, Gurmel Ghataora, and Samir Dirar. "Production of recycled plastic aggregates and its utilization in concrete." Journal of Materials in Civil Engineering 29, no. 4 (2016): 04016248. doi:10.1061/(asce)mt.1943-5533.0001765.

[15] Aitcin, P. C. "The use of superplasticizers in high performance concrete." High performance concrete–from material to structure (1992): 14-33. doi:10.4324/9780203475034.